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## At the Outer Limits of the International:

## Orbital Infrastructures and the Technopolitics of Planetary (In)Security[1]


### Abstract

As staples of science fiction, space technologies, much like outer space itself, have often been regarded as being 'out there' objects of international security analysis. However, as a growing subset of security scholarship indicates, terrestrial politics and practices are ever more dependent on space technologies and systems. Existing scholarship in 'astropolitics' and 'critical astropolitics' has tended to concentrate on how such technologies and systems underpin and impact the dynamics of military security, but this article makes the case for wider consideration of 'orbital infrastructures' as crucial to conceptions and governance of *planetary* security in the context of the 'Anthropocene'. It does so by outlining and analysing in detail Earth Observation (EO) and Near-Earth Object (NEO) detection systems as exemplary cases of technological infrastructures for "looking in" on and "looking out" for forms of planetary insecurity. Drawing on and extending recent theorisations of technopolitics and of Large Technical Systems, we argue that EO and NEO technologies illustrate, in distinct ways, the extent to which orbital infrastructures should be considered not only part of the fabric of contemporary international security but as particularly significant within and even emblematic of the technopolitics of planetary (in)security.



*Keywords:* orbital infrastructures; planetary security; planetary defence; technopolitics; earth observation; near-Earth objects.


### Introduction

A burgeoning body of work within security studies has recently (re)turned to considerations of the ways in which technical and material infrastructures constitute a crucially important


[1] Acknowledgments: We would like to thank the organisers of and participants in the 'Astropolitics Collective' workshop, held at King's College London on 4th May 2017, out of which conversations this article was subsequently developed. Thanks also to Rens van Munster for providing feedback on an earlier version, and to the anonymous *EJIS* reviewers for their thoughtful comments and suggestions. Any errors or omissions that remain are, of course, entirely our own.

but complex element of world politics.[2] Even within that turn, though, consideration of space-based infrastructures and technologies has remained largely peripheral. This article seeks to redress that tendency. The justification for doing so lies not in the possible virtues of bringing a more 'marginal' area of study 'in' to the mainstream analysis of international security. Rather, space-based infrastructures have been integral components of world politics for decades and, as argued by the few scholars who have countered the view that space technologies exist at the outer limits of international studies, these infrastructures contribute significantly to how we come to know, understand and address the relationship(s) between 'international', 'global' and 'planetary' forms of security and insecurity.[3] Specifically, we interrogate the roles played by what we term 'orbital infrastructures' in conceptualisations and practices of security. In so doing, we extend the existing parameters of 'astropolitics' and 'critical astropolitics', discussed in more detail below as subfields of the wider study of space policy and technologies,[4] to take better account of re-emergent concerns with the study of 'planetary security'. The latter theme, broached initially by scholars in the 1950s but only periodically and intermittently since, has become especially pertinent and worthy of reconsideration in relation to what has more recently been termed the 'Anthropocene'. Indeed, a starting point of our argument and its contribution to existing debates is that although the study of 'astropolitics' and 'critical astropolitics' as disciplinary subfields most closely concerned with the study of outer space provides a valuable entry point into discussions of orbital infrastructures, the extent to which they currently address the critical role of such infrastructures as means to both understand and address forms of planetary *in*security has yet to be theorised and analysed fully.

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[2] See, for example, Daniel R. McCarthy, 'Introduction: Technology in world politics', in Daniel R. McCarthy (ed.), *Technology and World Politics: An Introduction* (London: Routledge, 2018), pp. 1-21; Maximilian Mayer and Michele Acuto, 'The global governance of large technical systems', *Millennium*, 43:2 (2015), pp. 660-83; Mark Salter (ed.), *Making Things International 1: Circuits and Motion* (Minneapolis: University of Minnesota Press, 2015); Mark Salter (ed.), *Making Things International 2: Catalysts and Reactions* (Minneapolis: University of Minnesota Press, 2016).

[3] The most notable of which is Daniel H. Deudney, in his work beginning from the early 1980s – see in particular, *Space: The High Frontier in Perspective*, Worldwatch Paper 50 (Washington, DC: Worldwatch Institute, 1982), and *Whole Earth Security: A Geopolitics of Peace,* Worldwatch Paper 55 (Washington, DC: Worldwatch Institute, 1983).

[4] As an established field of research, via journals like *Space Policy* and *Astropolitics*, as well as texts including Michael Sheehan, *The International Politics of Space* (London: Routledge, 2007); James Clay Moltz, *The Politics of Space Security: Strategic Restraint and the Pursuit of National Interests* (Stanford CA: Stanford University Press, 2008); Nayef Al-Rodhan, *Meta-Geopolitics of Outer Space: An Analysis of Space Power, Security and Governance* (Basingstoke: Palgrave Macmillan, 2012).

To provide greater detail in this respect, we outline and analyse systems of Earth Observation (EO) and Near-Earth Object (NEO) detection as case studies of orbital infrastructures. Our examination of EO and NEO is not intended simply to contribute to greater awareness of two curios at the outer disciplinary limits of international security studies. Instead, key parts of our argument and analysis are, first, that both EO and NEO, albeit in different and complex ways, are already part of contemporary world politics rather than marginal to it; and second, that debates surrounding EO and NEO infrastructures simultaneously challenge existing conceptions of security but also reproduce familiar debates, disputes and contestations. EO and NEO infrastructures and the debates surrounding their functions, technical affordances and implications for modern contemporary security, our analysis suggests, are Large Technical Systems operative at a planetary scale. In and of itself, this challenges the ontological assumptions of the disciplinary boundaries of the study of *international* security. The cases of EO and NEO also exhibit accompanying forms of 'technopolitics' indicative of ongoing efforts to grapple with and reconcile understandings of international, global and planetary (in)security. In that sense, we contend, orbital infrastructures should be taken into account within contemporary security studies, not just because they are progressively and materially important to world politics at a more general level but because they also inform and challenge conceptions of security in significant but complex ways.

To develop these arguments, the article first situates its discussions in relation to prior and recently re-emergent concerns within security studies with 'the planetary' as a context in which orbital infrastructures are particularly pertinent. It then moves to a more detailed discussion and outline of our understanding and conception of orbital infrastructures. We integrate and expand upon existing scholarship on space technologies on the one hand and infrastructures as 'Large Technical Systems' on the other by introducing and applying an explicitly 'technopolitical' focus on the ways in which technologies 'both create and constrain political possibilities'.[5] Indeed, we argue that a key feature of these orbital infrastructures is debate and contestation over precisely what kinds of political possibilities for planetary

[5] Gabrielle Hecht and Paul N. Edwards, 'The technopolitics of the Cold War: Toward a transregional perspective', in Michael Adas (ed.), *Essays on Twentieth Century History* (Philadelphia: Temple University Press, 2010), p. 274.

security are created and constrained by these Large Technical Systems. This is a key feature of governance discourses associated with these orbital infrastructures. To exemplify and add relevant empirical detail and texture to these discussions, the article then undertakes an analysis of EO and then NEO orbital infrastructures as, respectively, potential means of "looking in" on and "looking out" for planetary security. Each section provides both an overview of contemporary EO/NEO and an analysis of the technopolitical nature of the debates that surround them. In conclusion, the article reflects on what significance EO and NEO, and the wider conceptualisation and analysis of orbital infrastructures, might entail for the contemporary study of (planetary) security.

## Planetary (In)Security in the Anthropocene

Conceptions of 'the planetary' are revived and urgent topics of concern within security studies and in International Relations (IR) more generally. Where wider political philosophical reflections on and considerations of 'the planetary'[6] and 'planetarity'[7] seek to reflect on and highlight the implication of an 'ecological crisis' facing the Earth on a planetary scale, a growing number of voices have begun to argue that the nature of that crisis challenges and calls into question the disciplinary boundaries of IR, the limits of its utility as a field of study, and the conceptions of (in)security it has tended to assume. Thus do Burke *et al.*, for example, declare that in the context of climate change, the 'planet's watch is ticking ever louder, and too many diplomats and statesmen seem deaf to it; deaf to the running down of the world and the voices of those most affected by melting glaciers, rising waters, and drying continents'.[8] Complicit in this, 'International Relations has failed because the planet does not match and cannot be clearly seen by its institutional and disciplinary frameworks'.[9] Their critique of the epistemological, ontological and practical drawbacks of a branch of study

[6] For example, William E. Connolly, *Facing the Planetary: Entangled Humanism and the Politics of Swarming* (Durham: Duke University Press, 2017); Catherine Keller, *Political Theology of the Earth: Our Planetary Emergency and the Struggle for a New Public* (New York: Columbia University Press, 2018); Bruno Latour, *Facing Gaia: Eight Lectures on the New Climatic Regime* (Cambridge: Polity, 2017).
[7] Amy J. Elias and Christian Moraru (eds), *The Planetary Turn: Relationality and Geoaesthetics in the Twenty-First Century* (Evanston: Northwestern University Press, 2015).
[8] Anthony Burke, Stefanie Fishel, Audra Mitchell, Simon Dalby and Daniel J. Levine, 'Planet politics: a manifesto from the end of IR', *Millennium*, 44:3 (2016), p. 510.
[9] Ibid., p. 501. See also, Dahlia Simangan, 'Where is the Anthropocene? IR in a new geological epoch', *International Affairs*, 96:1 (2020), pp. 211-24.

originating from a focus on 'the international' in the context of *planetary* crisis is also echoed strongly elsewhere.[10]

Though they might assume particular contemporary urgency, concerns with planetary security – both in the use of the specific term and as a denotation of a wider concern with existential threats operative at a planetary scale – are not entirely novel. As an operational term, 'planetary security' was cited within international attempts in the 1990s to rework notions of global governance in a post-Cold War world. The 1995 Commission on Global Governance report, *Our Global Neighbourhood*, for instance, introduced planetary security as a conceptual rubric within which to overhaul international efforts to address threats to 'the planet's basic life-support systems'.[11] Closely coupled with emerging United Nations formulations of 'human security',[12] planetary security required a perspectival shift from traditional national security, the Commission argued, to other levels and fields of security, glossed in academic responses to these moves as a 'deepening' and 'widening' of security scale and emphasis.[13] A precise definition was elusive, but planetary security was conceived as a way of addressing anthropogenic threats to the global environment, their causal relationships with armed conflict, and the resultant effects on individual, national and collective security.

Indicating the extent to which the predominant institutional and disciplinary frameworks can be argued to have historically obscured and precluded 'the planetary' are the significant pockets of exception to that general rule. In the decades prior to the Commission's 1995 report, several international security scholars had already pre-empted the move to a concern with forms of planetary (in)security, with some, including John Herz, Richard Falk, and Daniel Deudney, articulating new international security arrangements to address environmental

[10] For example, Simon Dalby, 'Rethinking geopolitics: Climate security in the Anthropocene', *Global Policy*, 5:1 (2014), pp. 1-9; Cameron Harrington, 'The ends of the world: International Relations and the Anthropocene', *Millennium*, 44:3 (2016), pp. 478-98; Jairus Victor Grove, 'The geopolitics of extinction', in McCarthy, *Technology and World Politics*, pp. 182-203.

[11] Commission on Global Governance, *Our Global Neighbourhood* (Oxford: Oxford University Press, 1995), ch. 3.

[12] United Nations Development Programme, *Human Development Report: New Dimensions of Human Security* (New York: Oxford University Press, 1994).

[13] Barry Buzan and Lene Hansen, *The Evolution of International Security Studies* (Cambridge: Cambridge University Press, 2009), pp. 187-225.

threats and those of military technologies, both nuclear and informational.[14] Each focused on threats to human survival that operated at the level of the planet as a whole. As early as the 1950s, Herz proposed a programme of applied 'Survival Research' to address the twin perils posed by environmental destruction and nuclear weaponry to the human species, perils that provoked him to pose the question: 'How can a "planetary mind" be developed?'.[15] Herz channelled the spirit of Hans Morgenthau before him, who saw sense in developing 'a supranational political solidarity, one unified not against other states or peoples but rather the threat of extinction'.[16] He wrestled with how this would work in practice, even as he remained pessimistic about the chances of developing a planetary sense of security: 'At no time in modern history has security meant so much to him [humankind]; at no time has there seemed less hope of retrieving it'.[17] Falk argued that intersecting 'vectors' of nuclear weapons, war, population growth, pollution and resource depletion already meant that 'Only new organizational forms with a planetary scope that corresponds to the planetary dimension of the situation can offer any prospect of a timely, corrective and adequate response'.[18] Deudney, too, linked environmental and nuclear concerns in his investigations into alternative ways of ordering collective security, and addressed his explicit proposals for 'planetary security' to 'only those problems that are irreducibly planetary in scale'.[19]

Revitalised interest in planetary security is inherently bound up with the implications of the 'Anthropocene' as a defining addendum to the general themes previously broached by Herz, Falk and Deudney.[20] The concept of the Anthropocene, as taken up and engaged with across the social sciences, denotes a period in which humankind is identified as the dominant influence on the planet's geochemical, ecological and climatic systems, granting stratigraphic

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[14] John H. Herz, *International Politics in the Atomic Age* (New York: Columbia University Press, 1959); Richard A. Falk, *This Endangered Planet: Prospects and Proposals for Human Survival* (New York: Vintage Books, 1972); Deudney, *Whole Earth Security*.
[15] Herz, *International Politics*, p. 317.
[16] Campbell Craig, 'Classical realism for the twenty-first century', in Rens van Munster and Casper Sylvest (eds), *The Politics of Globality since 1945: Assembling the Planet* (London: Routledge, 2016), p. 84.
[17] Herz, *International Politics*, p. 223. See also, Tim Stevens, '*Exeunt omnes*? Survival, pessimism and time in the work of John H. Herz', *Millennium*, 46:3 (2018), pp. 283-302.
[18] Falk, *This Endangered Planet*, p. 97.
[19] Deudney, *Whole Earth Security*, p. 41.
[20] See, Daniel Deudney, 'Turbo change: Accelerating technological disruption, planetary geopolitics, and architectonic metaphors', *International Studies Review*, 20:2 (2018), pp. 223-31.

weight to the inscription of anthropogenic activities on the Earth.[21] Significant debate has centred on the question of when this epoch began but much less about how, when or whether it might end. After all, implicit within geological nomenclature is the notion of finitude: all stratigraphic units have a beginning and an end, a lower and upper temporal bound – their delimiting is, in Hom's terms, an act of purposive 'timing'.[22] The very idea of an Anthropocene is predicated not on positive visions of human influence on the Earth but on its negative, potentially irreversible, effects.[23] Often, planetary survival is deemed threatened on account of a combination of political myopia, moral neglect and corporate venality, as captured more specifically by, for instance, the alternative designation of the 'Capitalocene'.[24] For some, this in turn is seen to emanate primarily from geographically concentrated practices of industry and consumption, as in Grove's suggestion of the 'Eurocene'.[25] Climate change, environmental degradation, radically diminished biodiversity, pollution and resource depletion all pose threats to humanity's capacity to secure its own long-term survival and that of the wider biome. In short, the question of planetary security has moved centre-stage.

## Orbital Infrastructures: Expanding the Technosphere of Planetary Security

An appreciation of technology – or, more accurately, technologies – is, we argue, fundamental to understanding conceptualisations of planetary security and the Anthropocene. Debates over nomenclature notwithstanding, the vectors of our demise in this period are primarily technological,[26] and technologies provide us with much of the informational basis upon which to realise knowledge about our planetary predicament. Herz, Falk and Deudney's prior considerations of forms of planetary (in)security occurred amidst an increased sociopolitical awareness of 'globality' in the post-war period, spurred not only by nuclear and environmental concerns but also by both technological change and cognitive shifts

[21] Clive Hamilton, *Defiant Earth: The Fate of Humans in the Anthropocene* (Cambridge: Polity Press, 2017).
[22] Andrew R. Hom, 'Timing is everything: Toward a better understanding of time and international politics', *International Studies Quarterly*, 62:1 (2018), pp. 69-79.
[23] Delf Rothe, 'Governing the end times? Planet politics and the secular eschatology of the Anthropocene', *Millennium: Journal of International Studies*, 2019, doi: 10.1177/0305829819889138.
[24] Moore, Jason W. Moore (ed.), *Anthropocene or Capitalocene? Nature, History and the Crisis of Capitalism* (Oakland: PM Press, 2016).
[25] Grove, 'The geopolitics of extinction'.
[26] Deudney, 'Turbo change'.

engendered by the exploration of outer space.[27] Similarly, as Gorman observes, 'Perspectives and data derived from satellites in Earth orbit [have] been integral to the very apprehension of what is now being called the Anthropocene'.[28] This is not to argue that technologies possess intrinsic properties or capacities that determine social outcomes, or which produce a monolithic understanding of the world. Rather, it is to understand technologies as sociotechnical assemblages of human and nonhumans, as 'partners' in both the relational co-construction of knowledge and as producers of effects[29] that may in turn lead to and inform multiple different practices of what Daggett calls 'world-viewing' and 'world-making'.[30] Here, we are specifically concerned with relatively distinct forms of sociotechnical assemblages that we have termed 'orbital infrastructures': assemblages comprised of terrestrial, atmospheric and space-based systems, institutions, structures of governance and technologies. Two analytical considerations inform our choice and use of that term.

The first responds to Mayer and Acuto's call to 'dig deeper into the materiality of transnational infrastructures and technical complexity of multi-layered systems' that help constitute world politics.[31] This reflects their ambition to move 'technology' to the centre of the study of the international via analysis of 'Large Technical Systems' (LTSs): '*socio*-technically complex systems, where human and non-human elements are intertwined' within large-scale infrastructural networks of telecommunications, energy supply and transport, to name but a few.[32] Borrowing from Latour, they note that social relations are mediated within LTSs by diverse technological infrastructures, such as, they suggest, oil pipelines, vaccination response mechanisms, and satellite positioning systems. These 'missing masses' are often excluded from sustained attention within international security studies, even though such networks routinely traverse, underpin and are impacted by the boundaries of nation-states,

[27] Deudney, *Whole Earth Security*; Benjamin Lazier, 'Earthrise; or, the globalization of the world picture', *The American Historical Review*, 116:3 (2011), pp. 602-30; Rens van Munster and Casper Sylvest (eds), *Nuclear Realism: Global Political Thought during the Thermonuclear Revolution* (London: Routledge, 2016); Rens van Munster and Casper Sylvest, 'Introduction', in van Munster and Sylvest, *The Politics of Globality*, pp. 1-20.
[28] Alice Gorman, 'The Anthropocene in the solar system', *Journal of Contemporary Archaeology*, 1:1 (2014), p. 87.
[29] McCarthy, 'Introduction'.
[30] Cara Daggett, 'World-viewing as world-making: Feminist technoscience, International Relations, and the aesthetics of the Anthropocene', in J.P. Singh, Madeline Carr and Renée Marlin-Bennett (eds), *Science, Technology and Art in International Relations* (New York: Routledge, 2019), p. 40.
[31] Mayer and Acuto, 'The global governance of large technical systems', p. 678.
[32] Ibid., p. 667, emphasis in original.

security policies, and practices of global governance.[33] In common with critical geographers[34] and urbanists like Keller Easterling,[35] Mayer and Acuto contend that attention to infrastructures can illuminate the workings of power, resistance and identity in the contemporary world, as well as contribute to our understanding of how physical space and sovereignty are transformed under conditions of globalisation. This is consistent with the key claim of scholarship on 'critical astropolitics' that considers the extent to which space technologies further destabilise established notions of territorial space and sovereignty, as opposed to treating these technologies and their related infrastructures either as apolitical or as simply transposing terrestrial inter-state geopolitics onto the realm of outer space.[36] It connects too with wider discussions of different forms of 'technopolitics', defined broadly as 'hybrids of technical systems and political practices that produc[e] new forms of power and agency', and the related contention that space technologies in particular can and should be considered as 'technologies of world politics' owing to the ways in which they, often in a very literal sense, incorporate and allow for the envisioning of different conceptions of global security.[37]

A second and complementary consideration is that orbital infrastructures can help us address and reconsider what John Agnew calls 'the territorial trap' of IR,[38] and, by implication, its sub-fields across international politics and security. Agnew sought not to deny the importance of

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[33] Ibid., p. 662. See, Bruno Latour, 'Where are the missing masses? The sociology of a few mundane artifacts', in Wiebe E. Bijker and John Law (eds), *Shaping Technology/Building Society* (Cambridge, MA: MIT Press, 1992), 225-58.

[34] For example, Stephen Graham and Simon Marvin, *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition* (London: Routledge, 2001).

[35] Keller Easterling, *Extrastatecraft: The Power of Infrastructure Space* (London: Verso, 2014).

[36] Raymond Duvall and Jonathan Havercroft, 'Taking sovereignty out of this world: Space weapons and the empire of the future', *Review of International Studies*, 34:4 (2008), pp. 755-75; Jonathan Havercroft and Raymond Duvall, 'Critical astropolitics: the geopolitics of space control and the transformation of state sovereignty', in Natalie Bormann and Michael Sheehan (eds), *Securing Outer Space* (London: Routledge, 2009), pp. 42-58; Fraser MacDonald, 'Anti-*Astropolitik* – outer space and the orbit of geography', *Progress in Human Geography*, 31:5 (2007), pp. 592-615.

[37] Paul N. Edwards and Gabrielle Hecht, 'History and the technopolitics of identity: the case of apartheid South Africa', *Journal of Southern African Studies*, 36:3 (2010), p. 619. See also, Gabrielle Hecht (ed.), *Entangled Geographies: Empire and Technopolitics in the Global Cold War* (Cambridge, MA: MIT Press, 2011); Columba Peoples, 'Extra-terrestrial technopolitics: the politics of technology in space', in McCarthy, *Technology and World Politics*, pp. 182-203; Columba Peoples, 'Envisioning "Global Security"'? The Earth viewed from outer space as a motif in security discourses', in van Munster and Sylvest, *The Politics of Globality*, pp. 164-87; Daggett, 'World-viewing as world-making'.

[38] John Agnew, 'The territorial trap: the geographical assumptions of International Relations theory', *Review of International Political Economy*, 1:1 (1994), pp. 53-80.

territoriality to international politics but to historicise the geographical assumptions of IR as a way of demonstrating the contingency of the integuments of state and society and of the dominant system of national sovereignty. As Jill Stuart has shown, human interactions with and through outer space provide multiple opportunities to reconsider the nature of territory and sovereignty, both of which are confounded by space technologies and practices.[39] Agnew conceded subsequently that IR scholars had made great strides in exploring physical space from perspectives that do not presume it is structurally or territorially deterministic,[40] but the majority remain resolutely stuck in the terrestrial plane.

The concept of orbital infrastructures provides further analytical purchase with which to address this concern. Political geographers have provided us with sophisticated analyses of the vertical dimensions of power, from the aerial visions of drone technologies and other airborne military and policing assets to the subterranean urbanism of the modern city.[41] Similarly, geologists advancing the Anthropocene concept have recognised that anthropogenic artefacts are not limited to the apprehensible, terrestrial realm alone. Since 1957, satellites and orbital debris have extended an 'aerial technosphere' into and beyond the Earth's atmosphere.[42] As Zalasiewicz *et al.* argue in terms of the scope of the technosphere, 'human influence on materials extends globally, including deep underground and into outer space'.[43] This includes spacecraft voyaging far beyond our gravitational well and, in the case of electromagnetic signals, various Pioneer and Voyager missions and the New Horizons craft, past the boundaries of the heliosphere and beyond the solar system itself.[44] At the same time, the Earth is the net recipient of extra-terrestrial entities, in the form

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[39] Jill Stuart, 'Unbundling sovereignty, territory and the state in outer space: Two approaches', in Bormann and Sheehan, *Securing Outer Space*, pp. 8-23. See also, Natalie Bormann, 'The lost dimension? A spatial reading of US weaponization of space', in Bormann and Sheehan, *Securing Outer Space*, pp. 76-90.

[40] John Agnew, 'Still trapped in territory?', *Geopolitics*, 15:4 (2010), pp. 779-84.

[41] Respectively, Peter Adey, Mark Whitehead and Alison J. Williams (eds), *From Above: War, Violence and Verticality* (London: Hurst & Company, 2013); Stephen Graham, *Vertical: The City from Satellites to Bunkers* (London: Verso, 2016).

[42] Jan Zalasiewicz, Mark Williams, Colin N. Waters, *et al.*, 'Scale and diversity of the physical technosphere: a geological perspective', *The Anthropocene Review*, 4:1 (2017), pp. 9-22.

[43] Zalasiewicz *et al.*, 'Scale and diversity', p. 10. On the 'technosphere' concept, see also Peter K. Haff, 'Technology as a geological phenomenon: Implications for human well-being', in Colin N. Waters, Jan Zalasiewicz, Mark Williams, Michael A. Ellis and Andrea M. Snelling (eds), *A Stratigraphical Basis for the Anthropocene*, Special Publication 395 (London: Geological Society, 2014), pp. 301-309.

[44] Gorman, 'The Anthropocene in the Solar System'.

of solar and extra-solar radiation, meteorites and cosmic dust, which forces us to rethink any idea of the Earth as divorced from the wider cosmic environment.[45]

More generally, space systems and technologies, critical astropolitics scholars contend, are integral to what makes terrestrial politics 'work'. As Fraser MacDonald points out, Global Navigation Satellite Systems (GNSS) enable not only military invasions and drone strikes but are also crucial elements of all manner of terrestrial transport and geospatial positioning systems. Satellite infrastructures enable multiple and constant forms of location, surveillance and communications systems and practices that cross conventional distinctions between public and private, military and civilian.[46] In contrast to, and in critique of, classical geopolitical readings of outer space as a 'strategic high ground' to be dominated militarily – as originally advocated most notably in Everett C. Dolman's conception of '*Astropolitik'*[47] – MacDonald's articulation of critical astropolitics is equally attuned to evaluating the extent to which 'space is becoming *ordinary*'.[48] This does not assert the decline or disappearance of the 'exceptionalist' politics of space militarisation and its efforts to dominate near-Earth orbit, but rather locates it on a continuum with a more 'everyday' politics of outer space.[49] Hence, space 'is not some far-fetched or indulgent distraction from the "real world"; rather […] we need to think about the contest for outer space as being constitutive of numerous familiar operations, not only in respect of international relations and the conduct of war, but also to the basic infrastructural maintenance of the state and to the lives of its citizenry'.[50]

Building on such arguments, we propose that figuratively 'in between' the Earth and the cosmos and acting as a kind of mediator or permeable membrane between the two, there lies a diffuse 'layer' of 'orbital infrastructures' that is critical both in defining planetary

[45] Nigel Clark, 'Ex-orbitant globality', *Theory, Culture & Society*, 22:5 (2005), pp. 165-85.
[46] MacDonald, 'Anti-*Astropolitik*', p. 63. See also, Johan Gärdebo, Agata Marzecova and Scott Gabriel Knowles, 'The orbital technosphere: the provision of meaning and matter by satellites', *The Anthropocene Review*, 4:1 (2017), pp. 44-52; Peoples, 'Extra-terrestrial technopolitics', pp. 192-95.
[47] Everett C. Dolman, *Astropolitik: Classical Geopolitics in the Space Age* (London: Frank Cass, 2002).
[48] MacDonald, 'Anti-*Astropolitik*', p. 594, emphasis in original.
[49] Peoples, 'Extra-terrestrial astropolitics'.
[50] MacDonald, 'Anti-*Astropolitik*', pp. 610-11. See also, Jason Beery, 'Unearthing global natures: Outer space and scalar politics', *Political Geography*, 55 (2016), pp. 92-101; Oliver Dunnett, Andrew S. Maclaren, Julie Klinger, K. Maria D. Lane and Daniel Sage (2017) 'Geographies of outer space: Progress and new opportunities', *Progress in Human Geography*, 43:2 (2019), pp. 314-36; Lindy Newlove-Eriksson and Johan Eriksson (2013) 'Governance Beyond the Global: Who Controls the Extraterrestrial?', *Globalizations*, 10:2 (2013), pp.277-92.

insecurities and in proposed mitigation of those insecurities. The figurative language of membranes and layers belies the extent to which such orbital infrastructures are not simply comprised of objects placed and located in low- or near-Earth orbit; they are most often crucially dependent on Earth-based components such as ground stations, sensor networks and associated personnel and technicians. Rather than treating such orbital infrastructures as either literally or metaphorically 'out there', we suggest that the development and management of such infrastructures, and particularly of their space-based components, are indicative of the outgrowth of Earth's 'technosphere' and comprise systems and processes 'through which technological transformations of Earth's surface reach a geological scale' into outer space.[51] Functioning (and defunct) satellites are 'increasingly occupying Earth's orbital space',[52] and yet even if we take these as key nodal or emblematic technologies, as we do here, it is precisely as sociotechnical assemblages that we can only fully appreciate orbital *infrastructures* as made up of terrestrial, atmospheric and space-based systems, institutions and technologies. Our identification of these infrastructures as 'orbital' thus intends to draw attention, following Sheehan, to the functional differentiation of their distinct contributions to 'space security' in general. Sheehan distinguishes between the use of outer space for Earth security and defence and its use in protecting Earth from outer space threats.[53] Earth Observation falls in the former category, the monitoring of NEOs in the latter. A third category concerning the security of space assets themselves is not covered by this article.

## "Looking In": The Planetary Technopolitics of Earth Observation and Security

In keeping with the understanding of critical astropolitics outlined above, Gärdebo *et al.* argue that 'the contemporary problem [of a] thickening orbital technosphere' can be traced not only to the military imperatives of the Cold War but also to the 'emergence of functionalities where satellite data became a tool for environmental monitoring'.[54] The latter environmental impetus may be at least as significant as military drivers in expanding the Earth's technosphere, particularly in relation to infrastructures of Earth Observation. Earth

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[51] Gärdebo *et al.*, 'The orbital technosphere', p.44.
[52] Katarina Damjanov, 'Of defunct satellites and other space debris: Media waste in the orbital commons', *Science, Technology, & Human Values*, 42:1 (2017), p. 166.
[53] Sheehan, Michael, 'Definition of space security', in Kai-Uwe Schrogl, Peter L. Hays, Jana Robinson, Denis Moura and Christian Giannopapa (eds), *Handbook of Space Security* (New York: Springer, 2015), pp. 7-21.
[54] Gärdebo *et al.*, 'The orbital technosphere', p. 48.

Observation (EO) generally denotes practices for 'gathering of information by remote sensing or in-situ measurements about physical, chemical and biological conditions of the Earth system'.[55] EO has received relatively little consideration within mainstream security studies, but over two decades ago Karen T. Litfin argued of emergent EO systems and science that a 'major shift in the way knowledge about our planet is produced is now under way, a shift that is likely to have profound consequences for environmental politics in the coming decades […] Among participants and observers alike, the expectations are lofty, verging on the grandiose […] Yet th[is] celebratory discourse […] serves to mask deeper questions regarding the uses of science and technology in an unequal world'.[56]

As EO competences and functions continue to expand, Litfin's words resonate even more intensely today. Beyond the disciplinary bounds of international security studies a copious literature advocates and espouses not just the virtues but the necessity of EO in terms of perceived benefits for addressing issues of national, global and even planetary security. A common pattern in such advocacy is an opening passage that refers either directly or indirectly to issues of 'planetary (in)security' and anthropogenic processes of change affecting the Earth's surface, natural resources and climate, as key imperatives for developing and making use of EO infrastructures to assist in comprehending and addressing these 'global challenges'. As stated by Giuliani *et al.*, for example, the study of EO is required precisely because 'Comprehensive, coordinated and sustained observations of the Earth, acquired by satellites, ground, marine-based systems and airborne platforms, are essential for monitoring the state of the planet, increasing understanding of Earth processes, and enhancing predictability of Earth system behaviour'.[57] Elsewhere, and in terms of the wider promotion of EO services and capacities, the 'NewSpace' company Satellite Vu markets itself as aspiring to provide an invaluable 'service to those who tackle critical global issues', and notes that:

[55] Giuliani, Gregory, Hy Dao, Andrea De Bono *et al.*, 'Live Monitoring of Earth Surface (LiMES): A framework for monitoring environmental changes from Earth observations', *Remote Sensing of Environment*, 202 (2017), pp. 222-33.
[56] Karen T. Litfin, 'The gendered eye in the sky: a feminist perspective on Earth observation satellites', *Frontiers: A Journal of Women Studies*, 18:2 (1997), p. 26.
[57] Giuliani *et al.*, 'Live Monitoring of Earth Surface', pp. 222-23.

> Our planet is facing enormous global stresses that affect us all. In the last decade, we have produced more plastic than in the entire 20th century and plastic constitutes approximately 90% of all waste floating on the ocean surface […] excessive nutrients from sewage outfalls and agricultural runoff have contributed to the number of low oxygen (hypoxic) areas known as dead zones, where most marine life cannot survive, resulting in the collapse of some ecosystems. Piracy, arms smuggling, people trafficking and illegal fishing are conducted by clandestine ships that are currently hard to detect and identify […] Other issues related to population, natural resources and conflict are all matters of global concern, yet these occur prevalently in areas that are currently barely monitored by space-based systems.[58]

Founded in 2016 and led by its CEO Anthony Baker, Satellite Vu is currently seeking investment to address what it argues to be key gaps in current EO infrastructures. Baker claims that 'Using cutting-edge technology, Satellite Vu is looking forward to delivering transformative information that will enable users to see our world in a unique way and in more detail than ever before […] By using the incredible technology we have created for the good of the planet, we are providing the facts for our leaders to make the world a better place for future generations'.[59] Investors in the company will, therefore, help in promoting the global public good: 'This is more than a simple donation. It is an investment in our Planet'.[60]

'Lofty and grandiose' as they are (to borrow Litfin's phrase), the marketing rhetoric and aspirations of Satellite Vu, at least as things stand, far exceed its current capabilities. Satellite Vu has yet to launch a satellite, hence its appeal for public investment via crowdfunding and for 'seed money [that] won't buy a whole satellite but […] will get the ball rolling'.[61] Yet the promotion of the initiative in many ways condenses, as well as indirectly references, themes and issues in wider discussions of materially more developed Earth Observation (EO) technologies and infrastructures. As alluded to in Satellite Vu's critique of the current

[58] Satellite Vu, 'Plastics, pollution and pirates: Satellite Vu prepares to tackle humanity's global challenges', 2018, available at: {https://spacewatch.global/2018/03/satellitevu_prepares_to_tackle_humanity_challenges/} accessed 4 January 2019.
[59] Ibid.
[60] Ibid.
[61] Ibid.

insufficiencies and patchy nature of EO infrastructures, there exists already an extensive and complex set of technologies and initiatives devoted to EO. While these have received some attention within security studies as well as in political geography, this pales in comparison to the volume of discussion – and often advocacy – of EO within the natural sciences.[62] There, related themes to those distilled by the promotion of Satellite Vu tend to recur.[63] First, that EO technologies and infrastructures are particularly suited to 'visualising' and addressing specific kinds of 'global challenges', often those associated with anthropogenic processes of change and, in many cases, explicitly identified with the Anthropocene. Second, that existing EO technologies and infrastructures create an improved capacity to address these challenges but are under-used and under-developed. And third, that access to EO technologies and infrastructures and the forms of data they produce remains uneven, accompanied by a general debate that recurs around the extent to which EO data should be made publicly and freely available to all.

### *The Global Challenges of Earth Observation*

As suggested by the prevalence of the themes identified above, elements of a planetary EO infrastructure already exist or are in development. More generally, existing EO technologies and the practical forms of data, knowledge and awareness they enable are increasingly considered essential to understanding and addressing a plethora of 'global challenges'. Discussions of EO often focus on very specific aspects of particular EO technologies, processes or technical issues, beginning from the level of 'global challenge(s)' before delving into the minutiae of specialised fields of knowledge and expertise. These include: the monitoring and

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[62] For social science analyses, see Monica M. Brannon, 'Standardized spaces: Satellite imagery in the age of big data', *Configurations*, 21:3 (2013), pp. 271-99; Jeremy W. Crampton, *Mapping: A Critical Introduction to Cartography and GIS* (Oxford: Blackwell, 2010); Daggett, 'World-viewing as world-making'; Litfin, 'The gendered eye'; Karen T. Litfin, 'Satellites and sovereign knowledge: Remote sensing of the global environment', in Karen T. Litfin (ed.), *The Greening of Sovereignty in World Politics* (Cambridge, MA: MIT Press, 1998), pp. 192-222; Karen T. Litfin, 'The status of the statistical state: Satellites and the diffusion of epistemic sovereignty', *Global Society*, 13:1 (1999), pp. 95-116; Philipp Olbrich, 'Technological expectations and global politics: Three waves of enthusiasm in non-governmental remote sensing', *Space Policy*, 47 (2019), pp. 107-16; Peoples, 'Extra-terrestrial astropolitics'; Nina Witjes and Philipp Olbrich, 'A fragile transparency: Satellite imagery analysis, non-state actors, and visual representations of security', *Science and Public Policy*, 44:4 (2017), pp. 524-34..

[63] See also, Oran R. Young and Masami Onoda, 'Satellite Earth observations in environmental problem-solving', in Masami Onoda and Oran R. Young (eds), *Satellite Earth Observations and Their Impact on Society and Policy* (Singapore: Springer Open, 2017), pp. 3-30.

management of the Earth's climate, biodiversity and ecosystems;[64] humanitarian and disaster response via enhanced capabilities for 'rapid mapping';[65] and mapping of deforestation[66]and the scope and scale of 'bare ground gain', defined as 'complete land conversion from vegetative cover to non-vegetative cover'.[67]

Similarly and more comprehensively, Gorelick *et al.*– employees of Google and hence invested proponents – celebrate the powers afforded by 'Google Earth Engine' as a form of 'Planetary-scale geospatial analysis for everyone' that potentially allows us to visualise a multitude of challenges to an unprecedented degree.[68] They proselytize that the Engine – a cloud-based platform for visualization of geospatial datasets, including a public data archive of satellite imagery and historical earth images going back more than forty years[69] – 'brings Google's massive computational capabilities to bear on a variety of high-impact societal issues including deforestation, drought, disaster, disease, food security, water management, climate monitoring, and environmental protection'.[70] In short, EO technologies and their corresponding infrastructural capacities are promoted as affording new and improved ways by which to visualise, in the form of satellite imagery in particular, the kinds of global challenges noted above. They also offer enhanced information in the form of 'geospatial big data', through which the precise nature of these challenges can be better understood and addressed.[71] As a consequence of the capacities of EO orbital infrastructures to provide both imagery and data, it is sometimes even claimed that EO is radically altering our sense of the planet itself and the place of humans on it. Sumi, for example, claims that 'Earth observation

[64] Ayodele Adekunle Faiyetole, 'Potentialities of space-based systems for monitoring climate policies and mitigation of climate process drivers', *Astropolitics*, 16:1 (2018), pp. 28-48; Harini Nagendra, Paola Mairotab, Carmela Marangic *et al.*, 'Satellite Earth observation data to identify anthropogenic pressures in selected protected areas', *International Journal of Applied Earth Observation and Geoinformation*, 37 (2015), pp. 124-32.
[65] Giuliani *et al.*, 'Live Monitoring of Earth Surface', p. 232.
[66] Matthew C. Hansen, Peter V. Potapov, Rebecca Moore *et al.*, 'High-resolution global maps of 21st-century forest cover change', *Science*, 342 (2013), p. 852.
[67] Qing Ying, Matthew C. Hansen, Peter V. Potapov *et al.*, 'Global bare ground gain from 2000 to 2012 using Landsat imagery', *Remote Sensing of Environment*, 194 (2017), p. 162.
[68] Noel Gorelick, Matt Hancher, Mike Dixon *et al.*, 'Google Earth Engine: Planetary-scale geospatial analysis for everyone', *Remote Sensing of Environment*, 202 (2017), pp. 18-27.
[69] Google Earth Engine, 'A planetary-scale platform for Earth science data & analysis', available at: {https://earthengine.google.com/} accessed 4 January 2019.
[70] Gorelick *et al.*, 'Google Earth Engine', p.18.
[71] Olbrich, 'Technological expectations', p. 107; Brannon, 'Standardized spaces'.

satellites have opened all of our eyes and, in the process, made us acutely aware of the importance of our planet's environment […] Earth observations also provide intangible and philosophical benefits. Their views remind us that we are all global citizens of planet Earth, living together in a fragile ecosystem that requires our utmost care and respect, urging international peace and cooperation'.[72]

And yet, as intimated by Litfin's (1997) concerns noted above, and in more recent scholarship on 'the politics of globality',[73] there is not necessarily a straight line running from technologies of Earth Observation to 'mutual understanding', conceptions of 'global citizenship' or, indeed, agreed understandings of planetary insecurities. As Paul Edwards succinctly puts it, 'globalities' – that is, plural understandings of the global – 'turn out to be a tangled set of messy, contradictory, often failed or incomplete projects that look very different depending on who you are and where you stand […] most "global" things – the economy, international law, common futures, the Framework Convention on Climate Change – are in fact lumpy, disjointed, full of holes and dropouts, much more network-y than spherical'.[74] Rather than constituting a seamless means of 'looking in' on, observing and acting upon 'global challenges' facing the planet, EO infrastructures and practices provide a further and particularly apposite illustration of Edwards' point. Even the more celebratory accounts of EO often allude to the technological gaps, systemic incompleteness and uneven institutionalisation of EO infrastructure such that it may not even be meaningful to speak of 'EO infrastructure' in the singular. The existence of initiatives such as the 'Group on Earth Observations' (GEO) and its 'Global Earth Observation System of Systems' (GEOSS) in and of itself evidences a perceived need to develop 'a set of coordinated, independent Earth observation, information and processing systems that interact and provide access to diverse information for a broad range of users in both public and private sectors'.[75] Current forms of space-based EO technologies and systems are, as GEO's drive towards improved coordination and integration indicates, multiple and variegated in nature and type. This includes, but is not limited to organizations and initiatives such as: NASA, including Landsat, plus multiple 'Earth Observation Data'

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[72] Akimisa Sumi, 'Foreword', in Onoda and Young, *Satellite Earth Observations*, pp. vii-viii.
[73] van Munster and Sylvest, 'Introduction'.
[74] Paul N. Edwards, 'Afterworld', in van Munster and Sylvest, *The Politics of Globality*, pp. 190, 189.
[75] GEO (Group on Earth Observations), available at: {http://www.earthobservations.org/index2.php} accessed 4 January 2019.

initiatives including Earth Science Data, LANCE (Land, Atmosphere Near real-time Capability for EOS), NASA Worldview, NASA Earth Observatory, and specific systems such as ICESat-2;[76] the EU Copernicus/European Space Agency (ESA) Sentinel programme; Japan's GOSAT project for monitoring greenhouse gases from space;[77] and private-corporate initiatives, such as the aforementioned Google Earth Engine, GEOSS, and others like DigitalGlobe.[78]

### *Back Down to Earth: EO Governance Gaps and Glitches*

Groups like the 'International Advisory Board Workshop on Assessing the Impact of Satellite Earth Observation on Society and Policy' have pointedly noted that 'Earth observations should be regarded as critical societal infrastructure',[79] hence endorsing the general valorisation of EO in this respect and advocating for its greater coordination and integration within unified structures of governance and regulation. EO, they argue, is too important to the functioning of modern life to allow the situation to be otherwise. But as the history of EO has repeatedly shown,[80] design and implementation decisions have always been subject to competing interests and corporate desires that have led to a range of fractured, complex and divergent initiatives and systems. Implicit within advocacy of EO is the strong sense that the very capacity to 'observe' the Earth as a whole *should*, in turn, correspond with and generate a single system of EO governance. However, although they may at times couch the virtues of specific applications of EO within broader narratives of 'global challenges', Anthropocene imperatives and the virtues of planetary scale perspective, scientists and academics working with forms of EO systems and data are often less wide-eyed about the extent to which EO technologies in practice lend themselves to integration of systems and perspectives. Hansen *et al*., for example, in their widely-cited work on deforestation note that 'International policy initiatives, such as the United Nations Framework Convention of Climate Change Reducing

[76] Robert S. Pearlman, 'Last Delta II rocket launches NASA satellite to map Earth's ice with space laser', *Space.com* (15 September 2018), available at: {https://www.space.com/41850-nasa-icesat2-laser-launches-on-last-delta-ii-rocket.html} accessed 22 May 2019.
[77] GOSAT, 'Greenhouse gases observing satellite GOSAT "IBUKI"', available at: {http://www.gosat.nies.go.jp/en/} accessed 4 January 2019.
[78] DigitalGlobe, 'See a better world with high resolution satellite imagery', available at: {https://www.digitalglobe.com/} accessed 4 January 2019.
[79] International Advisory Board Workshop on Assessing the Impact of Satellite Earth Observation on Society and Policy, 'Summary of conclusions', in Onoda and Young, *Satellite Earth Observations*, x.
[80] Pamela A. Mack, *Viewing the Earth: The Social Construction of the Landsat Satellite System* (Cambridge, MA: MIT Press, 1990).

Emissions from Deforestation and forest Degradation (REDD) program […] often lack the institutional investment and scientific capacity to begin implementation of a program that can make use of the global observational record; in other words, the policy is far ahead of operational capabilities'.[81]

The political, contested and 'messy' (to quote Edwards) nature of EO orbital infrastructures is in many ways best exemplified by reference to ongoing and contentious debates surrounding the issue of access to EO technologies and the data they produce. Characterisations such as that noted from the International Advisory Board Workshop above often refer in somewhat anodyne terms to the potential benefits of EO to 'all stake-holders and end users', and hence the rationale not just for EO itself but for coordination of institutions and systems at a global level. Access to (data produced by) EO technologies and infrastructures remains uneven, however, and there is a general debate surrounding EO as to the extent to which EO data should be made publicly and freely available.[82] The general consensus amongst authors and analysts is that EO data should be so available, but this almost always comes with caveats about the complexities of what 'public' and 'free' might entail in this context and the potential limits to both.[83] In addition, corresponding practical issues about accessibility arise, with the obvious precondition for the use of, for example, cloud-based EO datasets being internet access as well as requisite forms of computer hardware and software. 'In passing', Harris and Baumann note, in their otherwise detailed discussion of EO and open data policies, 'some countries in the less economically developed world do not yet have ubiquitous internet at low cost, so […] the concept of open Earth observation data over the internet is not always valid'.[84]

That characterisation simultaneously highlights and belies (in its brevity) the complex and unequal political economy of EO. It is not simply that there are complex constellations of 'public' and 'private' actors and interests within the 'global' assemblage of contemporary EO.

[81] Hansen et al., 'High-resolution global maps', p. 852.
[82] Gorelick *et al*., 'Google Earth Engine'; Clement Atzberger, 'Advances in remote sensing of agriculture: Context, description, existing operational monitoring systems and major information needs', *Remote Sensing*, 5 (2013), pp. 949-81; Mariel Borowitz, *Open Space: The Global Effort for Open Access to Environmental Satellite Data* (Cambridge, MA: MIT Press, 2017).
[83] See, especially, Ray Harris and Ingo Baumann, 'Open data policies and satellite Earth observation', *Space Policy*, 32 (2015), pp. 44-53.
[84] Ibid., p. 51.

As has been addressed in forensic detail by Mariel Borowitz, the accompanying rhetoric of 'global challenges' and 'planetary perspective' that surrounds EO systems and initiatives is rendered even more complicated once it is recognised that access to the data they produce is often subject to multiple 'exceptions'.[85] As the term suggests, the nature of these exceptions varies, with some forms of EO data restrictions arising from international law, others from data protection laws, commercial laws and imperatives, or privacy regulations.[86] Commonly, foreign policy and national security imperatives also lead to authorised exceptions on and restrictions to EO data. Thus, for example, does the European Commission reserve the right to 'restrict the dissemination' of data and information from the Copernicus Earth Observation programme (the European Union's flagship EO initiative for environmental monitoring) where such dissemination is deemed to present 'an unacceptable degree of risk to the security interests of the Union or its Member States'.[87] In cases such as this, environmental and national security imperatives for EO become less clearly distinct.

Different kinds of 'security' rationales are thus operative in and striate the global politics of contemporary EO as a form of orbital infrastructure, as do contending political and profit-seeking agendas.[88] While the surrounding discourse most often tends to 'celebrate' EO technologies and data as conducive to clarifying, understanding and addressing planetary problems and 'global challenges' as a matter of urgency, a more fine-grained and critical eye on the politics of EO suggests a more complicated 'picture' in which contending and less benign logics of security and (geo)surveillance are at play. On this reading, while EO might well be argued to be central to contemporary discourses of 'planetary (in)security', not least those associated with the onset of the Anthropocene, neither the technological forms that EO takes nor the types of 'spatial knowledge production'[89] they sustain can be taken as 'post-political'.[90] In fact, the opposite may be the case. EO might instead more accurately be characterised as constituting an inherently (techno)political example of contending visions of

[85] Borowitz, *Open Space*.
[86] Harris and Baumann, 'Open data policies', p. 52.
[87] European Commission, 'Explanatory memorandum', 7 December 2013, C(2013) 4311 final, p. 14, available at {http://ec.europa.eu/transparency/regdoc/rep/3/2013/EN/3-2013-4311-EN-F1-1.Pdf} accessed 22 May 2019.
[88] Molly K. Macauley, 'Earth observations in a National Space Strategy', *Astropolitics*, 8:2-3 (2010), pp. 205-19.
[89] Crampton, *Mapping*, p. 3.
[90] See also, Daggett, 'World-viewing'; Peoples, 'Extra-terrestrial technopolitics'.

security: a form of orbital infrastructure that is variously conceived of by key 'stakeholders' as potentially promoting and protecting corporate interests as much as global public goods; as allowing for enhanced border monitoring as much as envisioning a shared planetary space; and as preserving the status of the most technologically capable to survey the planet, rather than necessarily distributing the responsibility for and ability to respond to 'global challenges'.

### "Looking Out": The Planetary Technopolitics of Near-Earth Objects and Security

EO technologies' promise of planetary oneness is fractured once the political economy of orbital infrastructures is explored and the competing claims to planetary security are shown to (re)produce forms of inequality and insecurity. Moreover, the perspectival flattening of the Earth's surface via the verticality of observation may mask the heterogeneity of the Earth object itself, obscuring the operations of power as much as it purports to identify and address issues of planetary concern. When we look outwards from Earth, structures and objects also appear across a single plane of vision. The early modern application of reason and optical technologies showed this to be illusory and we now perceive the vast depth and texture of the universe beyond the Earth. 'Looking out' from the Earth requires shifting from an *areal* apprehension of our planet from orbit to a *volumetric* appreciation of cosmic spatiality.[91] Here too the theme of governing planetary security comes into view. Concerns with anthropogenic threats to humankind and 'extinction events' have been accompanied in recent decades by growing comprehension of extra-terrestrial hazards emanating from these outer space volumes. This includes Near Earth Objects (NEOs), solar system bodies whose orbits bring them into possible collision with Earth and with orbital assets. A large NEO collision with Earth would be hugely energetic and cause great harm to natural and human systems.

Most NEOs burn up in the atmosphere without causing damage to life or property, or are too small to constitute a threat. Larger objects may ablate insufficiently in the upper atmosphere and either hit Earth at high velocity or explode as low-altitude airbursts, as famously occurred over eastern Siberia in 1908 and over Chelyabinsk, Russia in 2013.[92] The former event levelled

[91] See, Stuart Elden, 'Secure the volume: Vertical geopolitics and the depth of power', *Political Geography* 34 (2013), pp. 35-51.
[92] Duncan Steel, *Rogue Asteroids and Doomsday Comets* (Chichester: John Wiley, 1995), pp. 173-83; Ian Sample, 'Scientists reveal the full power of the Chelyabinsk meteor explosion', *The Guardian* (7 November

over 2000 square kilometres of forest; the latter, a mere 20 metres in diameter, caused 1500 injuries and property damage across hundreds of square kilometres. At the other end of the scale, and attested by the geological record, the Chicxulub impact, 66 million years ago in what is now Mexico's Yucatán peninsula, was caused by a large asteroid, 10-15 kilometres in diameter. It is implicated in the Cretaceous-Tertiary mass extinction event that eliminated three-quarters of all species, including most dinosaurs.[93] Were a similar event to happen today, humanity might be at risk, if not from the immediate impact then from subsequent climate change and environmental degradation.[94] Extinction-scale events are exceptionally rare, but 'civilisation-destroying' impacts – 1-2 kilometres in diameter, 1 million megaton-equivalent – may occur every 100,000 years.[95] More common (10-100,000 years) are impacts by smaller NEOs up to 500 metres in diameter, which would have substantial regional implications, especially from earthquakes, firestorms and tsunamis.[96]A large NEO collision with Earth would be hugely energetic and cause great harm to natural and human systems. The United Nations Office for Outer Space Affairs consequently identifies such NEOs as 'potentially catastrophic threats to our planet'.[97]

IR scholars have rarely explored the articulation of NEOs with planetary security, or examined the technopolitics of the orbital infrastructures developed to identify, monitor and mitigate NEOs. Sheehan has identified the general threat to human security from outer space phenomena, whilst noting the potentially problematic securitisation of natural phenomena.[98] He argues, however, that securitisation of dangers originating from the 'space environment' itself is warranted, due to the existential risk they pose.[99] Deudney observes that NEO collision events might help foster a sense of 'Earth security' or 'planetary security', particularly in the

2013), available at: {https://www.theguardian.com/science/2013/nov/06/chelyabinsk-meteor-russia} accessed 22 May 2019.

[93] Charles Frankel, *The End of the Dinosaurs: Chicxulub Crater and Mass Extinctions* (Cambridge: Cambridge University Press, 1999).

[94] As identified by the originator of the 'Anthropocene' concept; see, Paul J. Crutzen, 'Geology of mankind', *Nature*, 415 (2002), p. 23

[95] William Napier, 'Hazards from comets and asteroids', in Bostrom and Ćirković, *Global Catastrophic Risks*, p. 225.

[96] Napier, Ibid., 229-30.

[97] UN Office for Outer Space Affairs, 'Near-Earth Objects', 2020, available at (https://www.unoosa.org/oosa/en/ourwork/topics/neos/index.html) accessed 10 February 2020.

[98] Sheehan,' Defining space security';

[99] Sheehan, 'Defining space security', p. 18.

face of a 'globally catastrophic' collision.[100] Deudney's argument contrasts with those promoting outer space regimes that prioritise national military and commercial interests, such as Dolman's *Astropolitik*.[101] Instead, he adopts a more obviously liberal astropolitical stance by proposing that the temporal and existential urgency stimulated by the prospect of a disastrous collision will require a global sense of communality hitherto lacking in global politics.[102] Writing in 2003, Deudney also pointed to emergent institutional arrangements and technoscientific infrastructures that recognised the NEO threat and aimed to understand and mitigate it.[103] The following discussion extends aspects of this foundational IR work on NEOs by addressing NEO detection, monitoring and mitigation infrastructures and how they articulate with and (re)produce notions of planetary security and insecurity.

*NEOs and Space Situational Awareness*

Modern science has revealed past NEO collisions such as Chicxulub and enabled the recording and analysis of contemporary events like Chelyabinsk and many less visible incidents. It has further catalysed an understanding that NEOs should be regarded as a valid object of anticipatory security on the planetary level. Buzan and Wæver, for instance, submit that NEOs might qualify as a 'universal physical threat' against '[a]ll states, and all nations, and all faiths, and all people'.[104] Moltz states more emphatically still that managing the NEO risk 'qualifies as one of the most common interests among all countries on Earth'.[105] NEO science and policy has therefore shifted from mere observation and retrospective analysis into more proactive modes of detection, monitoring, prediction and mitigation. These recognise both the potential global impact of NEOs and the need to develop effective NEO infrastructures on a planetary scale.

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[100] Daniel H. Deudney, 'High impacts: Asteroidal utilization, collision avoidance, and the outer space regime', in W. Henry Lambright (ed.), *Space Policy in the Twenty-First Century* (Baltimore: Johns Hopkins University Press, 2003), pp. 168.
[101] Dolman, *Astropolitik*.
[102] Deudney is, however, enthused by the secondary commercial functions of asteroid science and exploration; see also, Daniel Deudney, 'Forging missiles into spaceships', *World Policy Journal*, 2:2 (1985), pp. 271-303.
[103] Deudney, 'High impacts'.
[104] Barry Buzan and Ole Wæver, 'Macrosecuritisation and security constellations: Reconsidering scale in securitisation theory', *Review of International Studies*, 35:2 (2009), p. 264.
[105] James Clay Moltz, *Crowded Orbits: Conflict and Cooperation in Space* (New York: Columbia University Press, 2014), p. 87.

Through practices of Space Situational Awareness (SSA), orbital infrastructures play key roles in 'looking out' into outer space volumes for threats to human life and property, including from NEOs. At its most abstract, SSA is 'the ability to know what is happening in space'.[106] More concretely, it is a mode of hazard detection concerned with threats from orbital debris, space weather and NEOs. Orbital debris ('space junk') consists of manmade objects derived from failed or defunct satellites, spacecraft and associated equipment, which have yet to fall back to Earth. The potential for fast-moving debris to damage spacecraft is well-established, as is the possibility that impact events could cascade out of control ('Kessler Syndrome'), thereby rendering volumes of near-Earth space unusable. Significant attention is paid to the identification, cataloguing, monitoring, avoidance and, potentially, removal of orbital debris.[107] Space weather is less amenable to prediction and mitigation, as it consists in the effects on terrestrial and space-based systems of solar – and, potentially, cosmic – radiation, the causes of which are wholly outside human control.[108]

All three SSA fields are associated with extensive terrestrial and orbital arrays of detection, monitoring and early-warning technologies, in both civilian and military-intelligence domains, which in practice often overlap and reinforce one another.[109] Some, like the US military's Space Surveillance Network (SSN) are rooted in post-WWII superpower competition.[110] Others are more recent but also identify with terrestrial political entities, like the European Space Agency's (ESA) Space Situational Awareness Programme.[111] These assemblages of Earth- and space-based infrastructures are deemed essential to a host of other dependent activities. The European Union, for instance, has designated these services and their orbital assets critical infrastructures and objects of anticipatory security in and of themselves. SSA can therefore be considered within wider frameworks of critical infrastructure protection and

[106] Joan Johnson-Freese, *Space as a Strategic Asset* (New York: Columbia University Press, 2007), p. 236.
[107] Bleddyn Bowen, 'Cascading crises: Orbital debris and the widening of space security', *Astropolitics*, 12:1 (2014), pp. 46-68.
[108] Emma Kiele Frey, 'The risks and impacts of space weather: Policy recommendations and initiatives', *Space Policy*, 28:3 (2012), pp. 180-84.
[109] Stefan A. Kaiser, 'Legal and policy aspects of space situational awareness' *Space Policy*, 31 (2015), pp. 5-12.
[110] Charles Coombs, *Spacetrack: Watchdog of the Skies* (New York: William Morrow, 1969).
[111] European Space Agency, 'Space situational awareness', available at {https://www.esa.int/Our_Activities/Operations/Space_Situational_Awareness} accessed 22 May 2019.

resilience.[112] Nor is SSA restricted to state actors and agencies, as commercial and academic entities compete to provide novel applications in orbital space, particularly in the field of orbital debris mitigation.[113]

*NEOs and Orbital Infrastructures*

In the long term, SSA technologies may become 'a precondition of our capability to access space on acceptable security/safety terms and to conduct operational activities'.[114] This illustrates the priorities of NEO infrastructure activities: to determine the orbital and material characteristics of such objects and to assure their continued monitoring. They also aim to develop mitigation strategies should they be required. A thick matrix of national and international initiatives has arisen, involving state, private and hybrid actors and, through organisations like the B612 Foundation and the Spaceguard Foundation, the third sector. The most developed national programme is in the United States, where NEO risk is articulated in the *National Near-Earth Object Preparedness Strategy and Action Plan.*[115] NASA's Planetary Defense Coordination Office (PDCO) in Washington, DC is the day-to-day point of contact for many aspects of US NEO risk management.[116] It collates data from the Space Situational Awareness components of the US Air Force and from NASA's own NEO Observations Program, which includes groups like the Minor Planet Center, responsible for the formal designation of minor solar system bodies, and the Center for Near-Earth Object Studies.[117] Should a Potentially Hazardous Object be discovered, the PDCO would coordinate communications to government, media and the public and help formulate response plans within the broader framework of national and international disaster preparation and recovery.

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[112] Phillip A. Slann, 'Anticipating uncertainty: the security of European critical outer space infrastructures', *Space Policy* 35 (2016), pp. 6-14.
[113] Damjanov, 'Of defunct satellites'.
[114] Bertrand de Montluc, 'SSA: Where does Europe stand now?', *Space Policy*, 28:3 (2012), pp. 199-201.
[115] NSTC (National Science and Technology Council), *National Near-Earth Object Preparedness Strategy and Action Plan* (Washington, DC: White House, 2018).
[116] NASA, 'Planetary Defense Coordination Office', available at: {https://www.nasa.gov/planetarydefense/overview} accessed 22 May 2019.
[117] Center for Near Earth Object Studies, 'NEO basics', available at: {https://cneos.jpl.nasa.gov/about/neo_groups.html} accessed 22 May 2019. Objects are only defined as NEOs if they come closer than 0.3 AU to Earth, i.e., approximately 45 million kilometres.

The European Space Agency performs similar functions for its 22 member-states and partner organisations through its 'Risky Asteroids' workstream.[118] It discovers and tracks NEOs, predicts and warns of Potentially Hazardous Objects and, like the PDCO, is involved with the development of NEO mitigation technologies. Much of the NEO data flowing into this SSA-NEO system comes via the Minor Planet Center in the US, which collates data from international astronomical partners, including amateur volunteers. These are further processed by the NEO Coordination Centre in Italy, which calculates NEO orbits and risk profiles. If Potentially Hazardous Objects are identified, SSA-NEO advises on risk mitigation and communication, as the PDCO does in the United States. SSA-NEO is in the process of being upgraded to a fully-fledged ESA NEO capability, including the construction of its own ground-based survey and early-warning Near Earth Object Survey Telescope (NEOSTEL) system, also known as Flyeye. As the name suggests, these telescopes mimic insects' compound eyes, using multiple lenses that expand the field of view available for scanning the night sky for NEOs. ESA hopes that they will be able to detect any NEO above 40 metres in diameter at least three weeks prior to an Earth impact.[119] The first NEOSTEL installation is due to become operational in Sicily in 2020, with a further three sites planned, at least one of which will be in the southern hemisphere.

NASA and ESA are, along with national space agencies and individual observatories, members of the International Asteroid Warning Network (IAWN), which further coordinates NEO observation and reporting. Members are encouraged to share 'survey telescope operations; critical follow-up observations; orbit computation and hazard analysis; observations to characterize specific NEOs; data distribution, processing, and/or archiving; or other analysis and infrastructure contributions'.[120] This clarifies once more that orbital infrastructures are complex assemblages of ground- and space-based assets. Additionally, such arrangements should be understood not merely through the lens of physical artefacts but also with attention to the knowledge and informational systems in which they are embedded. Central to IAWN's

[118] European Space Agency, 'Risky asteroids', available at: {https://www.esa.int/Our_Activities/Space_Safety/Risky_asteroids} accessed 22 May 2019.

[119] 'ESA's bug-eyed telescope to spot risky asteroids', *Space Daily* (12 September 2014), available at: {http://www.spacedaily.com/reports/ESAs_bug_eyed_telescope_to_spot_risky_asteroids_999.html} accessed 22 May 2019.

[120] IAWN, 'Statement of intent for participation in the International Asteroid Warning Network', 9 March 2014, available at: {http://iawn.net/documents/iawn_statement_of_intent.pdf} accessed 23 May 2019.

work is the development of communications policy and protocols, should an NEO be identified as sufficiently hazardous to require international public and political engagement.[121] At present, a NEO event is very unlikely – asteroid 2009 FD has a 1 in 710 chance of hitting Earth in March 2185, which translates as a 99.86% chance of missing Earth[122] – but the preparatory logic is clear. NEO scenarios are also 'war-gamed' at the biennial International Academy of Astronautics Planetary Defense Conference and other events, to help test and refine these processes.[123]

IAWN was established in 2014 as a result of recommendations endorsed by the UN Committee on the Peaceful Uses of Outer Space, part of the UN Office for Outer Space Affairs. The UN Office works closely with IAWN and another organisation established by the same process, the Space Mission Planning Advisory Group (SPMAG). SPMAG's remit is to plan and promote international collaboration on 'space mission response activities', including NEO deflection.[124] It would be SPMAG's task to coordinate any international mission to prevent an imminent NEO strike, but it represents the tip of a global iceberg of counter-NEO research and development. Many suggested technologies are speculative, like ion beam shepherds, solar ablation and gravity tractors.[125] Others like kinetic impactors merely require suitable spacecraft to intercept an NEO with sufficient energy to nudge it from its path. In the case of nuclear deflection methods, the debate is less about the feasibility of delivering an explosive device than its effectiveness once there, as well as the ethics and law of nuclearizing spaceflight.[126] National space programs have demonstrated since 1996 (NEAR-Shoemaker) that close rendezvous with distant NEOs is possible; NASA's OSIRIS-REx and Japan's Hayabusa-

[121] Linda Billings, 'Words matter: a call for responsible communication about asteroid impact hazards and plans for planetary defense', *Space Policy*, 33:1 (2015), pp. 8-12.
[122] Center for Near Earth Object Studies, 'Sentry: Earth impact monitoring', available at: {https://cneos.jpl.nasa.gov/sentry/vi.html} accessed 22 May 2019.
[123] Center for Near Earth Object Studies, 'Planetary Defense Conference Exercise – 2019', available at: {https://cneos.jpl.nasa.gov/pd/cs/pdc19/} accessed 22 May 2019.
[124] United Nations Office for Outer Space Affairs, *Near-Earth Objects and Planetary Defence*, June 2018, p. 117, available at: {http://www.unoosa.org/documents/pdf/smpag/st_space_073E.pdf} accessed 22 May 2019.
[125] National Research Council, *Defending Planet Earth: Near-Earth-Object Surveys and Hazard Mitigation Strategies* (Washington, DC: National Academies Press, 2010).
[126] Jinyuan Su, 'Measures proposed for planetary defence: Obstacles in existing international law and implications for space arms control', *Space Policy*, 34 (2015), pp. 1-5.

2 missions are recent examples.[127] In October 2022, NASA's Double Asteroid Redirection Test (DART) mission will test the kinetic impaction technique on the smaller 'moonlet' of the binary NEO Didymos.[128] This will be the first test of any technique to change the motion of an NEO in space.

### *NEO Infrastructures and Planetary In/security*

The initiatives noted above do not exhaust the organisational, institutional and technical frameworks for monitoring and mitigating NEOs, but do provide an indicative sense of the complex technopolitics of NEO orbital infrastructures. As a putative form of global governance, the question remains as to who is being served by these arrangements, above and beyond the scientific communities that comprise the bulk of their membership. Recalling Deudney's suggestion that NEOs might help engender a sense of 'planetary security', how plausible is this, particularly should an NEO impact be imminent? In the 2017 IAA Planetary Defense Conference simulation exercise, the predicted 'corridor of impact locations' passed through 'Japan, China, Kazakhstan, Russia, northern Europe, and the British Isles', and into the North Atlantic.[129] What geopolitical considerations might creep in – or opportunities arise – if national interests are prioritised above those of the collective? Each of the countries and regions in this scenario poses different political questions for major actors. Would the US consider Kazakhstan, a leading provider of orbital launch capability, 'more important' than Russia and thereby more worthy of collaboration? Might China calculate risk differently if Xinjiang were a more likely impact zone than Beijing or Shanghai? What levels of likely human casualties and climatic disruption are deemed 'acceptable' or otherwise across a range of imaginable scenarios? We can perhaps surmise that were an NEO impact thought to be species-threatening, a truly planetary response would be forthcoming, but what of events below that threshold? Who will – or, indeed, who can – pay for hugely expensive NEO-mitigation missions, particularly if time is short? As a participant in the 2019 IAA exercise

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[127] Jonathan Amos, 'Osiris-Rex: NASA probe arrives at asteroid Bennu', *BBC News* (3 December 2018), available at: {https://www.bbc.co.uk/news/science-environment-46428018} accessed 22 May 2019; Paul Rincon, 'Hayabusa-2: Asteroid mission exploring a "rubble pile"', *BBC News* (19 March 2019), available at: {https://www.bbc.co.uk/news/science-environment-47633649} accessed 22 May 2019.

[128] NASA, 'Double Asteroid Redirection Test (DART) Mission', available at: {https://www.nasa.gov/planetarydefense/dart} accessed 22 May 2019.

[129] Available at: {https://cneos.jpl.nasa.gov/pd/cs/pdc17/pdc17_pr1.pdf} accessed 22 May 2019.

observed, any such decision 'obviously carries a lot of geopolitical concerns, a lot of concerns of power'.[130]

To illustrate this further, NEO infrastructures are dominated by space-faring nations, including at the United Nations level. As established elsewhere, the US exerts a dominant, perhaps even hegemonic, influence upon space security and space affairs.[131] Moreover, groups like IAWN are comprised of self-selected nations with the scientific and space-technical capacity to contribute; no African or Middle Eastern countries, or Asian ones outside China and South Korea, are signatories to the IAWN Statement of Intent. This does not prevent non-IAWN countries from becoming involved in NEO activities or other space-related initiatives, nor does it diminish their contributions to UN space cooperation activities and the development of space law, but it does reflect long-standing disparities in national capacities, borne principally of colonial legacies across the Global South.[132] It also reminds us that many of the US activities, in particular, are closely bound up with military and intelligence spheres, an historical artefact of the Cold War and US space administration, perhaps, but one that still registers in fields like SSA, in which orbital infrastructures are effectively dual-use military and civilian. In the specific field of NEO mitigation, US researchers and military scientists have long collaborated, despite concerns about the potential weaponisation of space.[133]

The vision of planetary security proposed by Deudney and others, and channelled through multilateral counter-NEO efforts at the UN and in scientific research, is therefore disturbed by terrestrial geopolitics and pursuit of national interests. In the absence of an imminent NEO threat, the issue remains primarily political, rather than a security issue per se. As Buzan and Wæver observe, attempts 'to construct physical threat universalisms [like climate change and

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[130] Meghan Bartels, 'Even if we can stop a dangerous asteroid, being human may mean we don't succeed', *Space.com* (8 May 2019), available at: {https://www.space.com/asteroid-deflection-human-error-planetary-defense.html} accessed 22 May 2019.
[131] Havercroft and Duvall, 'Critical astropolitics'; Brandon J. Weichert, 'The high ground: the case for US space dominance', *Orbis*, 61:2 (2017), pp. 227-37.
[132] Peter Redfield, *Space in the Tropics: From Convicts to Rockets in French Guiana* (Berkeley, CA: University of California Press, 2000); Sheehan, *The International Politics of Space*, pp. 124-41; Peter Sutch and Peredur Roberts, 'Outer space and neo-colonial injustice: Distributive justice and the continuous scramble for dominium', *International Journal of Social Economics*, 46:11 (2019) , pp. 1291-1304.
[133] Felicity Mellor, 'Colliding worlds: Asteroid research and the legitimization of war in space', *Social Studies of Science*, 37:4 (2007), pp. 499-531.

NEOs] in a macrosecuritisation of the planetary environment' have tended to fail as securitising moves.[134] This is because each polity or identity-group is its own referent object, rather than humanity as a whole. To shift NEOs from *politics* to *security* may require, as Deudney suggests, that 'a collision is anticipated authoritatively, or a highly visible (and perhaps destructive collision occurs'.[135] In contrast to the 'slow violence' of environmental change,[136] an imminent NEO strike might encourage cooperation in ways that climate change has not. This is not necessarily an argument *for* securitising NEOs; nor does it ignore the risks inherent in the securitisation of space, in general, which tends to exacerbate insecurities.[137] But it does suggest that global initiatives may still be subordinate to national interests and geopolitics, and fall short of being truly planetary in the sense intended here.

**Conclusion**

More than three decades ago in his *Space: The High Frontier in Perspective*, Daniel Deudney exhorted that 'It is time to abandon the view that space is some remote frontier where survival of the fittest is the law'.[138] Instead of focusing on space either as an extraordinary realm or solely as a form of strategic 'high ground' to be dominated militarily, our considerations, Deudney argued, needed to better incorporate and appreciate the ways in which 'near space' had by that point already become 'an extension of the human world'. As well as affecting everyday life, satellite infrastructures had come to underpin what he called 'earthkeeping tasks': practices aimed at understanding and preserving the planet's habitability. Our specific focus on EO and NEOs further highlights orbital infrastructures and their roles within the complex politics of informing and performing such 'earthkeeping tasks' in a context of growing concerns with planetary insecurities, particularly the climatic and ecological crises of the Anthropocene. We have sought to draw attention to the ways in which these orbital infrastructures help to take 'territory beyond *terra*'[139] by extending world politics into extra-planetary space via technological means.

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[134] Buzan and Wæver, 'Macrosecuritisation', p. 271.
[135] Deudney 'High impacts', p. 167.
[136] Rob Nixon, *Slow Violence and the Environmentalism of the Poor* (Cambridge, MA: Harvard University Press, 2013).
[137] Sheehan, 'Defining space security', pp. 19-20.
[138] Deudney, *Space,* p. 52.
[139] Kimberley Peters, Philip Steinberg and Elaine Stratford, 'Introduction', in Kimberley Peters, Philip Steinberg and Elaine Stratford (eds), *Territory Beyond Terra* (London: Rowman & Littlefield, 2018), pp. 12-13.

Considered in this way, Deudney suggested, 'Near space … just like the earth, is the site of ideological competitions, warped spending priorities, resource disputes and relative indifference to the interests of future generations'.[140] Yet the current context also suggests both added degrees of complexity and a compelling case to study the specificities of the technopolitics of orbital infrastructures, as we have tried to show in relation to EO and NEO. Approaching these orbital infrastructures as Large Technical Systems, but with specific attention to their technopolitics, counters the persistent sense that outer space is still or should remain a 'remote frontier' within international security studies. These infrastructures are subject to vagaries of commercial, geopolitical and institutional contentions amongst a plurality of actors and interests. Drawing attention to those aspects reduces to some degree the sense of 'remoteness' of orbital infrastructures from more familiar debates on global governance and within the broader study of the international. More distinctively, those contentions have been and are increasingly bound up with differing visions and initiatives for the provision of security on a planetary scale and with a view to the future habitability of the Earth, visions and initiatives in which conceptions of national, international, global and planetary (in)security are imbricated in complex and often contending ways. While terms such as 'global' and 'planetary' are commonly invoked with reference to both EO and NEO as seemingly self-evident scalar concepts – often as if universal understanding of, and consensus on, such concepts arise simply as an outcome of technological capacities to 'look in' on and 'look out' from the Earth – a more fine-grained analysis, as undertaken above, forces greater consideration of their more 'messy', 'disjointed' and political aspects. What planetary security entails, the ways in which it is being threatened, whether and to what extent it is compatible with national, international and global scales of understanding, and how various forms of technological and institutional infrastructures might be developed and employed to address these threats  is thus itself, we would argue, a key aspect of the techno*politics* of orbital infrastructures.

[140] Deudney, *Space*, p. 52.

Taking a technopolitical perspective thus allows us not only to draw attention to the 'large' nature of these 'technical systems'[141] but to analyse and *politicise* the ways in which these orbital infrastructures play a crucial role in defining and seeking to address forms of insecurity at the 'largest' possible planetary scale: whether that be in uses of Earth Observation systems to monitor our planet's condition, or in proposals to provide and govern infrastructures of planetary defence against Near-Earth Objects. Identifying and analysing the technopolitics of orbital infrastructures is consequently relevant to contemporary considerations of the international and is of wider practical and normative significance and, we hope, opens up scope for further avenues of research and critical engagement. Understood in these terms, these infrastructures for 'earthkeeping' provide not only instruments for 'world-viewing' – whether looking 'in' on the Earth or 'out' into the cosmos – but are always already entangled with particular forms of 'world-making'.[142] They help to constitute and inform multiple conceptions of the conditions within which politics takes place, and the terms in which planetary security is being understood.

Orbital infrastructures have existed at the 'outer limits' of international relations and security for several decades. However, as concerns with forms of planetary insecurity become central public and academic concerns, their salience is growing. Indeed, their importance is only likely to increase if current dynamics and trends continue, as extant infrastructures grow in scale and scope, and as new functionality is shifted into orbit. What novel forms of planetary insecurity will therefore be engendered and how will this affect the boundaries of the Earth as a planetary system? Both of the cases considered in this article point towards a tendency for orbital infrastructures to reproduce existing fault-lines and power imbalances of international security – leaving unclear the extent to which such infrastructures provide a sustainable basis for understanding and addressing human, environmental and other security threats in the context of the Anthropocene. Questions remain over how the authority to define and act upon such threats should be configured when security politics is 'scaled up' to the planetary. In this sense, we would suggest, critical considerations of orbital infrastructures should be brought in from the margins of international security and developed as an area of

[141] Mayer and Acuto, 'The global governance of large technical systems', p. 669.
[142] Daggett, 'World-viewing as world-making'.

research. They have much to tell us about how we conceive and address the limits of planetary (in)security.